Financial literacy learning in emerging markets: Agent-based modelling

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No. 2012-05

Series Editor: Dr. Alexandr Akimov

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Abstract
Financial literacy is a critical determinant of household well-being. We use an agent-based modelling approach to analyse the impacts of financial literacy programs delivered from sources of varying degrees of credibility through a social network in emerging economies. The simulation results indicate that the social networks of emerging markets rely heavily on source credibility to grow and sustain financial literacy levels. The results illustrate that financial education programs undertaken without regard for the context of the key social networks or source credibility neglect a main source of information flow and validation which can lead to program failure.

Key words: Financial literacy, agent-based modelling, emerging markets, social networks, media.

JEL Codes: I22, O16, C53

Software: NetLogo 4.1.2

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1. Introduction

Financial literacy - the ability to process financial information and make informed decisions about personal finance - has received growing attention in the developed world and, recently, in emerging markets as a critical determinant of household well-being. Financial literacy and related investment in financial products is of great concern in emerging market economies seeking to further develop their financial institutions and markets. Key stakeholders charged with responsibility to improve financial literacy include government agencies, consumer protection groups and insurers.

In many developed economies financial regulators are concerned that consumers lack a working knowledge of financial concepts and do not have the necessary tools to make economically rational decisions. The impacts of financial awareness deficiencies include poor money management practices, an inability to save for long-term goals, poor investment choices and insufficient finances for retirement. Ineffective money management can result in investment behaviours that adversely expose consumers during periods of financial crises. From a broader perspective, market operations and competitive forces are compromised when consumers do not have the skills to manage their finances effectively which limit or even prevent participation in the financial markets.

Developing countries have witnessed huge growth in a variety of financing mechanisms such as microfinance as well as associated micro-insurance and savings products. Households in emerging markets can choose between loan products from a variety of microfinance institutions (MFIs) along with insurance coverage for health, life, income, livestock, and weather events. Many of these products are quite complex and low levels of financial literacy may prevent consumers from making suitable decisions about financial products. A growing number of financial institutions and banks in emerging markets are providing support for both broad and focussed media campaigns aimed at improving the financial literacy of the population they look to engage as future customers. Financial literacy in the context of developing nations is the awareness of and familiarity with the range of simple financial products available to consumers such as savings accounts and insurance products.
This study proposes that two key elements influence the efficacy of financial literacy programs in emerging markets. Firstly the strong social network structure of emerging economies heavily influences the flow and validation of information through a community. Secondly the credibility of the source of information is also a critical aspect that influences the investment behaviour of individuals in emerging markets. The combined impact of these two related elements has important implications for the effectiveness of financial education programs aimed at increasing financial literacy. This study uses an agent-based modelling approach to analyse the likely impact of financial literacy programs delivered from sources of varying degrees of credibility through the social network and learning structures of emerging economies.

We confine our analysis to the study of exogenous impacts and social learning on financial literacy in emerging economies. The lack of financial literacy survey data in developing markets invites the use of novel methods to help predict likely effects of financial literacy programs. This study therefore develops a recursive feedback agent-based model (ABM) with social interaction capability and information source credibility parameters to generate scenario outcomes for a variety of emerging market characteristics such as existing literacy levels, media credibility, media penetration and urban versus rural settings. To calibrate the model to observed literacy and information source credibility levels, we use data from both developed and developing countries.

The model sequentially and iteratively addresses the interaction of two components. Firstly we discuss the main determinants of financial literacy and the relative importance of each. We then develop a model for a population comprised of individuals with varying levels of financial literacy and a given strength of social interaction. Upon calibrating the baseline model of financial literacy we run simulations of the model to observe the impacts of financial literacy through the social learning network using changing levels of source penetration and credibility. We also vary the population density to uncover the differences in literacy growth between urban and rural inhabitants. The study uncovers the major impediments of broad financial literacy education programs using traditional media and advertising channels in emerging economies.
The results from the ABM simulations indicate that the strong social networks of emerging markets rely heavily on source credibility to grow and sustain financial literacy levels in emerging economies. This outcome illustrates that financial education programs undertaken without regard for the context of key social networks or geographic barriers in an emerging economy neglects a main source of information flow and validation which can lead to program failure.

Section 2 discusses financial literacy and the impact on market participation in both developed and developing nations. Section 3 introduces the model framework and discusses the agent-based modelling approach to media influences and social interaction. Section 4 presents the results and Section 5 discusses implications of the simulation set used in the analysis. Section 6 offers some concluding remarks.

2. Financial literacy

A major consequence of limited financial literacy has been shown to be limited financial market participation, see Cole, Sampson and Zia (2009). Households in emerging economies unfamiliar with the notion of banking are unlikely to open a bank account and may instead store cash at home or invest in other stores of value such as gold which may be subject to greater risk. Choosing the wrong kind of savings product through a bank may result in an individual holding an illiquid instrument which charges substantial fees to withdraw. A borrower who is unable to understand the terms of a loan product may borrow money with inappropriate restrictions which may heighten the chance of missed payments and short-term cash flow problems leading to substantial financial penalties. Paradoxically, refraining from market participation may at times actually be in the best interests of financially illiterate individuals in emerging markets.

A large proportion of the population of developing countries are typically engaged in agriculture whose output is vulnerable to income shocks from weather events and commodity price volatility. Household savings are therefore a critical element for smoothing consumption and supporting longer-term investments in human and physical capital. Inflation risk is often substantial and financial literacy may help understand the best assets for investors that provide protection against inflation. Even a basic level of financial literacy can
help families in poorer countries understand the importance of the value implicit in the correlation of various assets to help households diversify risk efficiently.

An important characteristic that influences the effectiveness of financial literacy growth in emerging economies has largely been ignored in previous research. Strong social networks are a key feature of many developing countries where information can be disseminated quickly and positively reinforced. These networks can significantly contribute to social learning which acts as a critical source of information flow and validation. Successful persuasion seeks to bring about a change in an individual’s knowledge or attitudes about a particular issue. Significant changes in knowledge or shifts in attitude regarding a certain issue can generally be expected to drive a change in behaviour.

Research into the connection between financial literacy and household savings behaviour has been limited in emerging economies however in contrast a great deal of research has been conducted in developed economies. The characteristic differences in culture and social interaction between developed and emerging economies do not permit us to simply draw conclusions on ways of influencing financial literacy in the emerging markets using the features of developed markets as a proxy. Conclusions from research conducted into the financial literacy determinants of developed markets acts as an important starting point for examining the likely impacts of financial literacy programs in emerging economies.

2.1. Financial literacy in developed countries

Analysis carried out by a variety of researchers has shown that educated individuals in developed countries fared poorly on questions about credit management and personal finance. A survey of Australian consumers revealed that only 28 percent were able to correctly calculate compound interest, see OECD (2005) while the figure for American consumers was even lower at 18 percent, see Lusardi and Mitchell (2007b).

Households in developed countries with low levels of financial literacy tend borrow at higher interest rates, see Stango and Zinman (2009), they generally do not to plan sufficiently for retirement, they invest less and purchase fewer assets, see Lusardi and Mitchell (2007a), and
participate less in the formal financial system relative to more financially-literate individuals see Guiso and Jappelli (2005).

Financial literacy has been shown to be strongly associated with a person’s age, gender, education and socioeconomic characteristics. In the 2008 ANZ Survey of Adult Financial Literacy in Australia a number of subgroups had mean financial literacy scores which were significantly below the mean reported for the total sample. The subgroups included people aged 18-24 years and people aged 70 years or over, females whose formal education did not go beyond grade 10 of secondary school, those living in areas classified as having the highest levels of relative socio-economic disadvantage, those who speak a language other than English at home and those of Aboriginal or Torres Strait Islander descent, see ANZ (2008). In contrast the mean financial literacy score was significantly higher than that of the total sample for people aged 35-59 years, males, people who had completed a university degree and people living in areas classified as having the least relative socioeconomic disadvantage. These results point to a strong association between financial literacy and demographic/socioeconomic characteristics. However, this does not necessarily imply that all members of a particular population subgroup have low (or high) levels of financial literacy.

Financial literacy and product awareness also has a significant impact on stock-market participation rates in developed countries. The rate of participation in the stock market has a direct impact on the equity premium as shown in Makiw and Zeldes (1991), Heaton and Lucas (1999) and Brav, Constantinides and Gezcy (2002) and participation deficiencies have been shown to partially explain the equity-premium puzzle of Mehra and Prescott (1985). Importantly the level of social interaction in developed countries is an important driver of financial awareness and literacy modelled in Guiso and Jappelli (2005) and it is also a driver of stock-market participation shown in Hong, Kubik and Stein (2004).

The determinants of participation in stock markets have been studied in Abel (2001) and Guiso and Jappelli (2005) for the US and Italy respectively. These studies confirmed that stock market participation is strongly associated with increased wealth which can be partly explained by the presence of fixed investment costs acting as a deterrent for investing. Stock-market participation has also been found to an increasing function of education level. Education reduces the fixed costs of participating by facilitating investors to understand the
market’s risk-reward trade-offs, to set up accounts, to execute trades and administer the earnings and taxes of a portfolio. There is also a pronounced link between race and participation and related to this is the notion that social interaction plays a large role in influencing stock market participation rates. The growing body of empirical research that examines the importance of peer-group effects in other contexts such as Duflo and Saez (2002) where co-worker influence in the participation rate of employer-sponsored retirement plans, has important implications for this study. Social interaction and influence are therefore key drivers of stock-market participation through the lens of financial literacy. Evidence of social interaction effects on stock market participation described in Hong, Kubik and Stein (2004) provides support for the inclusion of social interaction effects in a model of financial awareness.

2.2. Financial literacy in developing countries

The definition of financial literacy applied to emerging economies used by the OECD and World Bank Group is the combination of individuals’ understanding of financial products and concepts and their ability and confidence to appreciate financial risks and opportunities, to make informed choices, to know where to go for help, and to take other effective actions to improve their financial well-being (OECD 2005).

A small amount of research has been conducted to analyse the impact of financial repression on financial development, see la Porta, Lopez-de-Silanes, Shleifer and Vishny (1998) especially in developing countries in the process of liberalising their financial markets. Development of a financial market however may not be sufficient to spur financial literacy development if demand for financial products and services remains limited.

As in developed countries, cognitive ability plays an important role in determining financial literacy in developing countries. Cole, Sampson and Zia (2009) studied financial literacy in India and Indonesia and found that both financial literacy and education levels are positive predictors of having a bank account and investing savings in financial products. They also found training programs targeted at individuals with low levels of education and financial literacy along with financial incentives in some circumstances can increase demand for financial services, however it is not always cost effective.
In India more than half of labourers surveyed by National Council of Applied Economic Research (2008) indicated that they store cash at home, while borrowing from moneylenders at high rates of interest. Financial illiteracy is often coupled with a lack of access to financial products or failure to use them even when they are available. For instance in Zambia and six other African countries only 29 percent of adults have a bank account and 50 percent use no financial products at all, see DFID (2008). A South African survey found that nearly 60 percent of the people surveyed do not understand the term interest while in Zambia, more than two-thirds of people are unfamiliar with basic financial products and tools such as checking accounts, automated teller machines and debit cards see Godfrey (2008).

Feng and Seasholes (2004) conducted research into the social network effect of investment behaviour in China. They found evidence of herding effects among individual investors who hold individual brokerage accounts in China. Investors in China seeking to place trades in person can do so only in the brokerage house in which they had opened their accounts. This enabled the Feng and Seasholes study to differentiate word-of-mouth effects from impacts due to a common reaction to releases of public information. They showed that the common reaction to public information (trades placed across branches in the same region) rather than word-of-mouth effects (trades placed in the same branch) were a primary determinant of herding.

Informed participants generally help create a more competitive, more efficient market. As knowledgeable consumers demand products that meet their short- and long-term financial needs, providers compete to create products having the characteristics that best respond to those demands, see Braunstein and Welch (2002). Some developed countries have responded to this evidence by advancing financial literacy programs as a low-cost intervention mechanism aimed at improving household financial decision making and ultimately increasing savings and welfare. The conclusions from Cole, Sampson and Zia (2009) required a carefully designed, focused and targeted financial literacy program, one that is more cost effective than a large-scale effort, may serve as a valuable complement to financial reform in emerging economies.
3. Model of financial literacy behaviours within social networks

Lasswell (1948) developed a transmission model of communication consisting of five components, namely source, message, target, channel and impact. While Lasswell’s research largely focussed on mass communication the transmission model can be applied to person-to-person communication. Other models of human communication, such as the Shannon-Weaver and Osgood-Schramm circular models incorporate feedback loops into the communication process and argue that communication is a circular rather than linear process, see Stone, Singletary and Richmond (1999).

Hovland and Weiss (1951) conducted empirical research into the effectiveness of educational campaigns and advertising and their effects on behaviour and public opinion. This analysis demonstrated the strong positive impact of source credibility on behavioural change. Under the conditions of the experiment, Hovland found that neither the acquisition nor the retention of factual information appears to be affected by the trustworthiness of the source, but changes in opinion are significantly related to the trustworthiness of the source. Furthermore in terms of their distinction between learning and acceptance Hovland showed that while the communication (premises, arguments, etc.) is learned and forgotten to the same extent regardless of the communicator, the extent of opinion change is influenced by both learning and acceptance, and an untrustworthy communicator will immediately degrade acceptance of the material. At the time of exposure individuals tend to reject information from less credible sources but over time disassociate the content and the source and gradually accept the less credible information. Regardless of the effects of time the credibility of the information source itself is therefore critical to the success of a financial literacy enhancement program aimed at changing the opinion of individuals.

For social learning to act as a valid source of information flow it should also consider the characteristics of successful and unsuccessful persuasion, as well as compliance, obedience, and resistance to authority. Individuals and groups can be influenced by verbal and non-verbal means. The arguments a source individual uses to persuade their targets are called their advocacy and if an individual’s advocacy is successful, then they are considered to have changed another’s belief or provided some level of information that has provoked a positive reaction.
The challenge of providing financial literacy training to consumers in emerging economies is difficult due to the wide variety of information needs arising from differences in prior experience, language, culture and financial situation. However the strong social networks established through communities, religion and caste can be the key to increasing and importantly sustaining financial literacy in emerging economies, so long as the source is seen as credible by the social network as a whole.

The primary determinants of financial literacy and the implications for investment participation will be described by a simple model. The output of the model will be embedded in a recursive feedback agent-based model (ABM) with social interaction capability and calibrated to a set of data. Inputs and outputs from the ABM will be used to describe the critical elements that affect financial literacy and investment behaviour. We make the key assumption that the probability of influencing an individual increases with greater and more complex positive social interactions in a given network.

3.1. The model

For a set of social interactions Latané (1981) demonstrated the importance of the three attributes of the relationship: strength - the social strength or persuasiveness of the individuals involved; immediacy - the physical or social distance between each individual; and population - the number of individuals an individual is exposed to. Using this basic framework we can construct a simple model for the social pressure felt by an individual within the network of a community.

When an individual is a target of another individual’s influence the level of social influence with respect to financial literacy (awareness of simple financial products) experienced by individual \( i \) from individual \( j \) can be represented by the following equation

\[ y_{i} = \frac{1}{N} \sum_{j=1}^{N} \frac{S_{ij} \cdot I_{ij} \cdot P_{ij}}{D_{ij}}, \]

where \( y_{i} \) represents the amount of social pressure exerted upon individual \( i \), \( S_{ij} \) represents individual \( i \)’s literacy level where +1, 0 and -1 represent full knowledge, no knowledge and complete rejection of financial products
respectively, represents individual i’s strength or influence level \( (S > 0) \), is a constant that represents an individual’s resistance to change , represents the geographical or other form of social distance between individuals i and j and represents the distance decay exponent for n individuals. We assume that knowledge or financial literacy can flow from less aware to more aware individuals and individuals currently considered financially literate can become financially illiterate given sufficient social pressure to reject investment opportunities. Equation (1) is a modification of the energy of an alliance configuration explored in Axelrod et.al. (1995).

Larger values of mean that individuals require a greater amount of social pressure to overcome the hurdles associated with their lack of knowledge. Higher levels of will result in an acceleration of the effect of increasing the distance between individuals and the subsequent effect on the amount of social pressure exerted by the financially literate on the less literate. Latané (1981) refers to the distance measure as immediacy and noted that it is an attribute of a pair of individuals which measures the ease of communication between two individuals.

External global influences such as media and advertising can be included in the model without loss of generality by adding a media influence term to Equation (1) to arrive at the following expression

\[
\text{Equation (2)}
\]

where represents the strength or influence media messages have on individual i with , and is the credibility level attributed to the media where +1, 0 and -1 represent total credibility, no credibility and complete mistrust of the media causing individuals to actually act in the opposite direction to that intended via the media message, respectively. The media is modelled as another agent in the social network, but with a fixed distance of 1 from each individual, implying perfect immediacy. The value of will vary from one individual to the next depending on the penetration rate of the media, thus each individual will experience a different degree of pressure imposed by an exogenous signal.
The need for the credibility parameter to vary from -1 to 1 is to cater for possible cultural resistance to financial literacy programs driven by cultural barriers, religious beliefs (for instance Muslim adherence to Sharia law prohibiting usury or investing in businesses that provide goods or services considered ‘haram’ or contrary to its principles) or other social behaviour that may limit an individual’s capacity to open a simple savings account or obtain insurance. This numerical range also permits the presence of activists who intimidate and construct information barriers in the social network preventing the growth of such knowledge.

3.2. Heterogeneous systems and agent-based modelling

Systems composed of multiple participants that interact to create feedbacks can be very sensitive to the actions of a small number of individuals that have particular characteristics. Therefore understanding the actions of the average individual is insufficient for explaining observed patterns and it is important to understand the nature of heterogeneity among individuals in a complex system. To better understand the principal causes and inflection points caused by heterogeneity in human systems computer models using agent-based techniques have developed over the past 15 years based on the pioneering research of Axelrod (1984, 1997a). Emergent or bottom-up behaviour materialises when a number of entities form more complex behaviours as a collective. Emergent behaviours are not easily predicted or deduced from the behaviour of the lower-level entities. An important element of emergence is that it challenges the assumption that complex behaviour must always be a result of complex rules. For example, flocking or swarming has been shown to be an example of emergent behaviour. From the analysis of Reynolds (1987) and extended by Huberman and Adamic (2004), flocking is controlled by three simple rules: collision avoidance, velocity matching and flock centring. Individual agents following these simple rules create complex motions and interactions from which the behaviour of the flock emerges. The simulation model presented in this paper draws heavily upon Latané’s theory of dynamic social impact and Axelrod’s study of energy of alliance configuration.

A realistic model for understanding the barriers to financial literacy must address the issues regarding social distance. We define geographical distance or physical proximity as the grid distance between two individuals. While geographical distance is an important factor in determining the frequency and intensity of social interaction it has often been ignored see
Tobler (1976) and Kellerman (1989). In addition to physical proximity other types of social distances or factors that influence the social interaction between individuals can be included. The analysis of McPherson, Smith-Lovin, and Cook (2001) as well as Hong, Kubik and Stein (2004) showed that individuals tend to have significant contact with others who share similar attributes or belong to similar affiliations like church groups. Social networks that form from shared socio-demographic characteristics has been referred to as homophily in Lazarsfeld and Merton (1954) and has a powerful effect on the information individuals receive and the attitudes they form.

One of the major factors influencing who individuals mix and communicate with is race or ethnicity. Age, religion, education, occupation and gender follow at around the same order, see McPherson, Smith-Lovin, and Cook (2001). Although these factors and their order of importance may vary from culture to culture they provide a useful starting point to extend Equation (2) by incorporating other measures of distance. However unlike physical measures such as geographic distance, measures such as ethnic or religious distance are more difficult to quantify. Additional social distance parameters can augment the social influence model by re-arranging Equation (2) as follows

\[ \text{Equation } (3) \]

where \( k \) represents a set of social distance factors. The distance decay factor is set at the same rate for all social distances for simplicity however individual decay exponents could also be applied to each social factor.

Limiting the size of an agent’s neighbourhood to a maximum of 8 grid spaces on all sides means that the summation notation in Equations (2) needs to be modified to reflect the truncation of the agent’s world. Equation (2) thus becomes

\[ \text{Equation } (4) \]

since the summation is not over all \( n \) agents in the simulation but only those agents within the extended Moore neighbourhood of agent \( i \), the set of which is denoted by \( M(i) \). We set the
parameter for the simulations in this study based on the analysis of similar values used in Latané (1981).

If the social pressure on individual $i$ is greater than zero then the individual will change their behaviour. The value of $\theta$ is a deterministic force or pressure felt by individual $i$ to change their opinion when the value of $\theta$. To incorporate a degree of randomness in the decision-making behaviour of individuals we employ the following rule based on the work of Kacperski and Holyst (1999):

$$\frac{d\phi_i}{dt} = \theta \cdot \left(1 - \frac{\phi_i}{\phi_{avg}}\right),$$  \hspace{1cm} (5)

where $\phi_i(t)$ is the opinion of individual $i$ at time $t$ with probability $P(\cdot)$ and represents the average volatility of the individuals in the simulation. The function described in Equation (5) is a sigmoid function which is real-valued and differentiable, having either a non-negative or non-positive first derivative. The s-shaped curve reflects the probability that an individual will change his or her behaviour in the next time step $t + 1$ given a certain value of $\theta$ at $t$.

The agents in the simulation are endowed with the following attributes:

- coordinate for geographic location: $\phi_{loc}$;
- social influence: $\Phi$;
- resistance to change: $\Gamma$;
- susceptibility to media influence: $\Psi$;
- preferred distance from $i$ to other individuals $j$: $d_{ij}$, and
- level of financial literacy: $\Phi_{fin}$.

The social influence and susceptibility to media influence parameters are truncated at zero for the first set of simulations so their distributions cannot be considered strictly normal. Negative random values obtained through the simulation are thus redrawn. At the beginning
of the simulation agents are created with varying values of these attributes. The geographic location of an individual is determined by the spatial attributes of the region of interest so individuals can be located either in a densely populated urban setting or in a rural area. Different geographies and their ability to act as barriers in the social network will be examined.

A grid size of 100 x 100 is selected which allows for a high level of detail while permitting execution of the simulation at a reasonable rate. The population of agents in the grid ranges from 500 to 2,000 which is a sufficient proxy to simulate social impact effects in emerging markets, see Axelrod (1997b). An agent’s neighbourhood is an extended Moore neighbourhood (eight cells surrounding a central cell on a two-dimensional square lattice) that extends up to 8 grid spaces on all sides. This limits an individual to a maximum number of 225 neighbours or sources of social influence. The simulation world is a torus so that the grid isn't bounded, but it wraps over the edge of the map to the opposite edge so that every patch has the same number of neighbour patches. If the grid size is large, as in this case, then limiting the size of an agent’s neighbourhood enables the simulation to execute faster with negligible effect on accuracy of the results.

An individual’s preferred distance to other individuals is determined by randomly drawing from a uniform distribution ranging from 1 to 5 to replicate the variability in the social network on individuals. Smaller values mean greater levels of social or cultural influence while larger values mean greater intolerance and thus resistance. Once assigned an agent’s tolerance does not change over the course of the simulation.

The impact of media penetration or influence on individual $i$ is determined by randomly drawing a number from a normal distribution with a mean of 2 and standard deviation of 1. The number representing media influence can be thought of as a score on a hypothetical questionnaire or similar instrument that measures the level of credibility assigned to the mass media by the respondent. Media influence and individual level of literacy for each individual are uncorrelated at the start of each simulation which means that financially literate individuals do not necessarily freely access media channels. Once assigned to an individual, media influence remains constant over the course of the simulation.
A constant is used to represent an individual’s resistance to external influence and is based on research into individual inertia by Nowak and Latané (1994) and Nowak and Lewenstein (1996).

The proportion of financially literate individuals is set at the beginning of the simulation. Level of financial literacy is randomly distributed among individuals regardless of geographic location or any other attribute. Willingness to change behaviour is the only agent’s attribute that changes over the course of the simulation. It is possible that an agent’s willingness to adopt investments may change more than once over the course of a simulation. Although an individual in the simulation has several attributes, it only has one behaviour; to change or maintain its willingness to adopt financial investments.

The model was implemented in NetLogo, see Wilensky (1999) which is a platform suited for simulating spatial logics driven by a multi-agent system.

3.3. Model Calibration

To ensure the simulation model represents real-world behaviour we calibrate the model to a number of known studies in both developed and developing nations. The developed markets used are Italy, USA and Australia while India and Indonesia are used as model calibration proxies for the emerging markets.

We employ the study conducted by Guiso and Jappelli (2005) in Italy for stock, corporate bond and mutual fund awareness over the period 1995 to 1998. Guiso and Jappelli found that stock awareness is positively correlated with education, household resources, long-term bank relations and proxies for social interaction. In addition, newspaper readership has a positive impact on awareness, and its coefficient is always highly significant. The financial literacy level in Italy as measured by the combined awareness of mutual funds, investment accounts and stocks is around 30 percent of the population. The financial literacy level in Italy as measured by knowledge of stocks alone was found to be around 50 percent. Furthermore they found that increasing newspaper readership from the lowest value provinces to the highest value provinces raises the probability of stock awareness by 5.4 percent and that of being aware of mutual funds, investment accounts and corporate bonds by 25, 23, and 21 percent respectively. Italy has a newspaper circulation of 121 per 1,000 people and 525 television sets per 1,000 people, along with radio receivers of 876 per 1,000, see Barca (1999) and Hibberd (2001). However the high level of concentration of ownership of the non-public media in
private hands translates into a deep mistrust of domestically produced news and related materials and therefore media influence is assumed to be low, see Hibberd (2001). We therefore set literacy levels at 30 percent for combined investment literacy and 50 percent for awareness of stocks, with media exposure of 52 percent and a relatively low level of media credibility at 0.1 for the calibration. The results are provided in Figure 1. From the simulation literacy levels do not diverge much from current levels indicating that the model is working properly given the above input parameters.

Figure 1: Calibration results for three developed markets (US, Italy and Australia) and two emerging markets (India and Indonesia).

In Australia the ANZ Financial Literacy Survey conducted in 2008 revealed that 76 percent of investors belong to a superannuation (pension) fund however less than 58 percent of investors understand the actual nature of their superannuation investment, see ANZ (2008). This level of literacy has increased from a level of around 45 percent for the same indicator in 2005, see ANZ (2005). The growth in financial literacy with respect to superannuation has been partially attributed to growth in media coverage and education programs over this period aimed at enhancing investors’ understanding of retirement savings and planning, see ASIC (2010). Australia has a newspaper circulation of 196 per 1,000 people and 524 television sets per 1,000 people, along with radio receivers of over 1,300 per 1,000, see McPhail (2002). Media influence is relatively high in Australia and the mainstream media is largely credible. Media exposure was set to the television ownership ratio of 52 percent and media influence set to a high level of 0.5. After calibrating the Australian results to the normal settings for developed Western countries the model converged to a literacy level of
around 61 percent, which is within the error bounds of the Australian survey result. Figure 1 illustrates convergence of Australia’s financial literacy level using the model.

Several financial literacy surveys have been conducted in the US that can be used for model validation. Survey data from the University of Michigan’s Survey of Consumers detected a general competent financial management level of around 60 percent for simple financial products, see Hilgert and Hogarth (2002). We use this measure of financial literacy to calibrate the model and ensure a state of equilibrium is reached given a level of media influence. The US has a newspaper circulation of 264 per 1,000 people and 788 television sets per 1,000 people, along with radio receivers of over 2,000 per 1,000. Media influence is therefore relatively high in the US and the mainstream media is seen as largely credible, see McPhail (2002). Media exposure was set to the television ownership ratio of 79 percent and media influence set to a high level of 0.5. After calibrating the US results the model converged to a literacy level of around 61 percent which is in line with our expectations. Figure 1 shows the results using the model.

Calibrating the model to emerging markets also requires general proxies since there is a large degree of diversity in the social characteristics of each market. For this analysis we employ financial literacy survey results that analyse the number of bank account holders in both India and Indonesia to validate the model. Only 12 percent of Indian and 41 percent of Indonesian households report having a bank account while in comparison, developed countries such as the US have around 88 percent of adults with a bank account (FINRA (2009)). Financial literacy has been shown to be a strong and consistent predictor of demand for financial services in India and Indonesia, see Cole, Sampson and Zia (2009). For media influence parameter estimates we use newspaper circulation and television set data for both India and Indonesia. India has a newspaper circulation of 50 per 1,000 people and 61.2 television sets per 1,000 people, see Khanna (2002). India has a strong press foundation with loyal readership and a relatively low level of media censorship which enhances its credibility. Indonesia has a newspaper circulation of 59 per 1,000 people and 60.2 television sets per 1,000 people, see Astraatmadja (2001). Indonesia has a developing print and broadcast media sector with varying degrees of output quality and news censorship which impacts on media credibility. We therefore set media penetration to a level at 6 percent for both countries and the strength of media credibility at a high level of 0.4 for India and at a relatively low level of
0.1 for Indonesia in the calibration. These results are portrayed alongside the developed country calibration results in Figure 1.

Figure 1 highlights the convergence of each market used in the calibration to a known stable level. The model calibrates reasonably well to social behaviour and media credibility observed in developed and developing countries within about 2,000 time steps which allows us to run simulations to test for the efficacy of financial literacy programs with a high degree of confidence in the validity of the results.

4. RESULTS

Each simulation used in the analysis employs the following assumptions:

- Population = 2,000 individuals;
- Degree of randomness in individual decision making is held constant for all initial condition levels;
- Social distance parameter for developed markets;
- Social distance parameter for emerging markets;
- The distance decay factor;
- Each agent’s sensitivity to media influence is drawn from a uniform distribution;

- Level of financial literacy for individuals is uniformly distributed; and
- Level of media credibility is uniformly distributed.

The social distance parameter is set to a higher level for emerging markets due to the strong collectivist culture and strong social network observed in many of the developing economies of Asia and South America. The time steps denote simulation time and not real time. One step in simulation time is measured as one set of interactions between an individual and the neighbours surrounding the individual. Therefore 2,000 time steps denote one round of interactions for a population of 2,000 individuals. Each simulation is run 20 times. The choice of 20 runs was found to provide an acceptable compromise between speed and
accuracy and allowed us to construct a confidence interval for each simulation, Wolfram (1983).

To demonstrate the structure of the grid using the model an example of a developed country with an initial state of 50 percent of the population financially literate with a high level of media penetration and credibility (social distance , and ) and its resulting final state are illustrated in Figures 2 and 3 respectively. The light cells denote individuals who are financially literate while darker cells have no knowledge of simple financial products. The clusters that form as the social interactions an outcome of the simulation can be clearly seen in Figure 3.
Figures 4 and 5 illustrate the grid outcomes for an emerging economy where the initial state of financial literacy is 20 percent while social distance is set to 1.5 with a mild level of media influence and credibility ( and ). Figure 5 demonstrates strong clustering behaviour even in the presence of only mild media influence. The strength of the social network in the model given by the high social distance parameter can often override media influences in developing nations as illustrated in this first simulation.

In the initial state the system is a spatially random distribution of financially literate and illiterate individuals. After running the simulating to account for the social and media impacts on every individual in the torus the simulation continues until no further changes in behaviour are observed and as such reaches equilibrium and then stops. When the state of equilibrium is reached the clustering of similar levels of literacy is observed. We will
demonstrate that this is particularly evident in areas of high population density. The tendency for stable clusters of literacy to emerge from an initially uniform distribution of literacy has been observed in empirical data in other settings, see Lewenstein, Nowak and Latané (1992), and is not an unexpected result. Clearly the initial level of financial literacy is a major factor in deciding the final level of literacy at equilibrium.

During each simulation the ratio of financially literate individuals to the total population is recorded. This is the literacy ratio used to estimate the efficacy of financial literacy programs under different initial conditions. The grid diagrams are provided to illustrate the clustering effect. Changes in literacy levels will be graphed to account for different social and economic environments in the remainder of the paper.

4.1. Financial literacy programs in the absence of media influence

This simulation tests for financial literacy growth in a developing country in the absence of media influence. Total information flow for financial literacy is through social influence and word-of-mouth only. The population is set to 2,000 representing a dense social network. This simulation is driven by the dynamics in Equation (4) with initial proportions of financial literacy in the population set from 0 to 100 percent in 20 percent increments.

The average levels of financial literacy at each initial condition are plotted in Figure 6. The results converge after a time period of around 2,000 steps.
The initial proportion of the population who are financially literate has a large impact on the equilibrium level of literacy. The effect is not uniform however, as a difference in the initial condition results in very different equilibrium outcomes. These results are largely similar to the general observation that the dominant group at simulation initiation becomes even more dominant in equilibrium, see Latané (1981). This simulation demonstrates some of the typical characteristics of agent-based simulations such as agent clustering, polarization and nonlinear changes in levels of literacy over time. The media-absent social influence simulations based on Equation (1) demonstrate how a dominant level of literacy in a population is expected to become more dominant, and only reach population saturation at high initial literacy levels. Literacy levels that commence at zero and 100 percent literate converge to zero and 100 percent respectively and are not depicted in Figure 6. Full saturation in the absence of mass media requires a very high level of literacy, in the order of 93 percent.

4.2. Simulating media influence

Media influence is modelled as a universal exogenous signal that influences each agent in the simulation via an influence factor and the level of financial literacy in the media as per Equation (4). Since the media does not influence all agents equally the simulation allows a random set of agents to attach a high degree of credibility to media messages and others to attach very little. The amount of credibility an agent attaches to a given media message is assumed to be uniformly distributed. In the simulation the media acts like another neighbour to each agent. Agents have access to the media however not all agents actively use the media as a source of information. In developing countries the level of media credibility varies which has an impact on the literacy growth.

By increasing both the mean of the random variable representing media influence in the population and the media credibility parameter the media’s opinion becomes more influential in the levels of literacy of each agent. The initial level of financial literacy is set at 20 percent for all simulations. The population is set to 2,000 representing a dense social network. The condition of no media influence is also included for comparison.
Figure 7 shows the effect of increasing media penetration or influence which can also serve as a proxy for the repetition frequency of media messages. In this set of simulations the media has a moderate level of credibility so that agents who receive the message respond positively to it.

The nonlinear growth in financial literacy given media influence from an initial level of 20 percent can be seen in Figure 7. The first few time steps witness the greatest rates of change in population literacy levels with greater levels of media sensitivity having correspondingly greater rates of change. Convergence is achieved after around 10,000 simulations for the higher media penetration rates. The simulation assumes that the media message continues at the same level of credibility over this time period, which may or may not be sustainable or cost-effective. However even at very high levels of media sensitivity financial literacy does not become universal as there are typically clusters of agents that will not be converted to financial literacy through social influence. Minority opinions often survive in a social margin, see Latané (1981) and Nowak and Latané (1994). However the effect of media influence on the general population to increased levels of financial literacy is clear.

Interestingly the analysis in Cole, Sampson and Zia (2009) found that financial education programs have only modest effects on stimulating demand for bank accounts among uneducated and less financially literate households. However the provision of small subsidies
for opening an account was shown to be a proper incentive for many individuals to open accounts even without financial literacy training. A follow-up study conducted two years after the initial incentive scheme showed that those who were originally offered the high incentives were significantly more likely to have used bank accounts in the past year to deposit, withdraw, send or receive funds. Their results suggest that the level of ‘media penetration’ can sometimes only be achieved and sustained through novel measures that act to reduce the price of financial services. Carefully designed, focused and targeted financial literacy programs can therefore stimulate financial reform through the social network indicated by the market penetration results of this simulation. It is possible that the notion of media influence be substituted for other forms of social influence such as education, directed marketing campaigns, sports sponsorship or government literacy programs. The simulation however does not distinguish between targeted campaigns and blanket coverage of agents who readily receive media signals, but assumes the appropriate media approach is used for each market.

A comparison of Figures 8 and 9 as well as 10 and 11 highlights the raw ability of information provided through the mass media to influence financial literacy. Even when literacy levels are very low the two highest levels of media influence quickly shift literacy levels above 60 percent. However when the mean media influence and media credibility levels are low the literacy level grows very slowly and converges to a level only slightly higher than the initial level. The large difference in population literacy at time step 4000 in Figure 8 shows the importance of media influence within a population where literacy is in the minority. By contrast, the improvement in literacy in a low media penetration and credibility environment in Figure 9 is quite small.
Figure 8: Developing country simulation for initial literacy level of 20 percent and varying levels of media penetration 20%, 40%, 60%, 80% and 100% with high media credibility ( , and ).

Figure 9: Developing country simulation for initial literacy level of 20 percent and varying levels of media penetration 20%, 40%, 60%, 80% and 100% with weak media credibility ( , and ).
Mass media messages appear to give the best return on investment in terms of increased literacy levels when the initial support is in the minority. This is an important result in terms of the cost-benefit trade-off for promoting financial products in communities. Once population literacy is above a certain threshold human and material resources that would otherwise have provided only small and rapidly diminishing returns can then be diverted to areas of greater need.
Negative media signals have a very noticeable effect on literacy levels, decreasing them to levels below the media-absent equilibrium. In nations where the mass media is known to be corrupt we interpret this as negative credibility. Using a fixed level of negative credibility we simulate the model for varying levels of media penetration in the community. As shown in Figure 12 as the media penetrates a higher proportion of the developing nation population, the behavioural change acts in the opposite way to that which the media message was intended due to the deep suspicion of the media held by individuals in a strong social network. Curiously for low penetration rates the social network dominates the negative credibility of the media message. In fact below penetration rates of around 40 percent the negative media message implied by the extreme low credibility level has minimal effect on changing the behaviour of individuals. The social network is able to dominate such that existing attitudes in the community towards financial literacy (opening bank accounts, microfinance, etc.) contribute to actual growth in literacy levels.

![Figure 12: Developing country simulation for initial literacy level of 20 percent and varying levels of media penetration %, 20%, 40%, 60%, 80% and 100% with negative media credibility ( , and ).](image)

This type of behaviour has been observed in other developing market settings. A polio vaccination campaign in India, which originally commenced in 1988, depended on announcements using radio, print, television, cinema, and posters to influence the public, with television and radio playing a more important role in the urban areas, see Srinivasan (2002). In addition to the pro-vaccination messages delivered through the mass media health
workers were the main information source in both rural and urban settings. Significant segments of the population rejected the message to have their children immunised for a variety of reasons such as the belief among some poorer and less-educated Muslim communities that the vaccinations were designed to sterilise Muslim children as part of a well-disguised form of genocide implemented by the Hindu-dominated Indian Health Department. Other problems for the information campaign included illiteracy, geographically isolated slums and rural areas, areas controlled by militant groups, difficulty contacting nomadic communities, a middle class avoidance of public health activities, doubts over the quality of the vaccination and a distrust of western medicine, see Srinivasan (2002). Distorted, negative and inaccurate reporting by sections of the media also caused confusion in the population. These negative influences directly affect population behaviour but as shown in Figures 10 and 12, these influences can generally be overcome through enhancing information source credibility and leveraging off the integrity of the social learning network.

4.3. Geographically restricted media influence

The ability to influence agents using a uniform or varied external influence (which may be regarded as mass-media broadcasts) can be used to conduct experiments on the effects of limiting media influence to only part of the landscape. The population was doubled from 2,000 to 4,000 in this simulation to make it easier to visually demonstrate and assess the effect of restricting media coverage. The simulation results were produced using Equation (4) with an initial literacy level of 20 percent, strong media penetration % and high credibility in the areas with media access, along with .

Figure 13 presents the results of the ratio of the level of financial literacy without media barriers to the level of financial literacy with three escalating levels of media barriers as a proportion of the population, at the 25, 50 and 75 percent levels. This simulation shows that sections of the population who cannot be easily reached through mass media due to geography, religion, language or other social barrier inhibits the efficacy of information flow through the social network. As shown in Figure 13 if only half the population has access to media channels, the expected literacy level in that half will be over 1.5 times greater than the portion of the population without media access. Figure 14 provides a simulation grid example when the upper-right one-eighth of the population is socially separated from the greater
population denoted by the arrow-shaped agents in contrast to the people shaped agents in the rest of the grid. This barrier or ‘non-broadcast’ area is relatively well defined due to the number of financially illiterate agents inhabiting the area. After performing a number of simulations it can be observed that there is a degree of permeability in the actual distribution of opinions near the edges of the two areas due to word of mouth information diffusion.

Figure 13: Ratio of literacy levels with no geographic barriers to varying levels of geographically restricted media penetration of 25%, 50% and 75%. Developing country simulation was for an initial literacy level of 20 percent with strong media credibility ( , , % (in areas with media access) and ).

Figure 14: Simulation grid results for a population with geographically restricted area in upper right eighth section of grid. Developing country simulation was for an initial literacy level of 20 percent with strong media credibility ( , , % (in areas with media access) and ).
Other broadcast black spots due to geographic features or political obstacles can be included in the model to aid in the planning of boundary penetration of information campaigns to hitherto restricted zones in a population. Figure 14 shows a degree of spill-over of both positive and negative behavioural changes along the border but the extent of the word-of-mouth spill over effect is not great. If the agents were free to move about the landscape rather than remaining fixed the spill effect may be greater.

4.4. Social influence and population density

Varying the number of agents on the landscape can simulate the effect of population density on behaviour change through information transmission. The clustering of behavioural shifts in financial literacy is more salient in densely populated areas than sparsely populated areas. The smaller average distance between agents in a highly dense population permits greater social pressure to be exerted on each agent in a simulation. To explore the effect of population density on behavioural changes in financial literacy, a series of simulations using four different levels of population density were carried out. All other factors in the simulation were held constant while the population density of the agents’ landscape was varied from low density (random allocation of agents in 20 percent of available cells) to high density (80 percent of available cells) in 20 percent increments. The simulation results were produced using Equation (4) with an initial literacy level of 20 percent, strong media penetration % and high credibility , along with and .

Figure 15 shows the convergence of financial literacy in varying degrees of population density. When compared with Figure 8 the results for the 80 percent population density level roughly coincides with a media penetration level of around 20 percent in a highly dense population (100 percent). This illustrates the difficulty in relying on social networks to support an information campaign in rural settings.
Figure 15: Literacy level convergence in rural areas with varying degrees of population density 20%, 40%, 60% and 80%. Developing country simulation was for an initial literacy level of 20 percent with strong media credibility (% and ).

Highly dense populations permit greater increases due to the influence of the media, given at least a moderate level of credibility. The immediacy of the media reinforces the social network response. The very low density simulation does not show much behavioural change among agents, and all of the change takes place in the first few time steps. The limited level of change is understandable accounting for the distance decay of social influence. Higher density populations however do not appear to reach an equilibrium condition sooner than the lower density populations. For an agent to change its behaviour it must be exposed to sufficient social pressure from agents who hold the opposite view.

The high level of social pressure experienced by agents whose neighbours are very close drops off rapidly with small changes in the average distance to the nearest neighbour. It is this high level of social pressure when neighbours are very close that leads to clustering of similar opinions. The tendency of like opinions to cluster can be seen in Figures 16 to 18 especially in the highly dense populations which can be used to represent urban areas.
Figure 16: Literacy level convergence in rural areas with low population density 30%. Developing country simulation was for an initial literacy level of 20 percent with strong media credibility ( , , % and ).

Figure 17: Literacy level convergence in semi-rural areas with medium population density 60%. Developing country simulation was for an initial literacy level of 20 percent with strong media credibility ( , , % and ).

Figure 18: Literacy level convergence in urban areas with high population density 100%. Developing country simulation was for an initial literacy level of 20 percent with strong media credibility ( , , % and ).
The more sparsely populated landscape in Figure 16 illustrates the difficulty in visually identifying clusters in rural areas. When the population is more sparsely distributed clusters are harder to identify and therefore targeted education campaigns are more difficult to construct. Extremely dense populations such as that in Figure 18 make it very easy to spot clusters of similar opinions by simple visual inspection.

The effect of media with negative credibility results in the same degree of clustering as shown in Figures 19 and 20, but with the financially literate being in the minority. Figure 19 is a semi-rural area and Figure 20 is an urban area.

Figure 19: Literacy level convergence in semi-rural areas with medium population density 60%. Developing country simulation was for an initial literacy level of 20 percent with negative media credibility ( , , % and ).

Figure 20: Literacy level convergence in urban areas with high population density 100%. Developing country simulation was for an initial literacy level of 20 percent with negative media credibility ( , , % and ).
The results presented in Figure 20 were then used as the initial point to simulate the effect of a media or education campaign that suddenly gains a modest level of credibility. The financial literacy level fell from 20 percent to 12 percent as illustrated in Figure 20, and then increased to 50 percent using the same media penetration rate of 0.5 with media credibility set to 0.2 as shown in Figure 21. This simulation was used to demonstrate that low literacy levels formed in clusters can be recovered in an environment where the credibility of the information source is improved.

![Figure 21: Literacy level convergence in urban areas with high population density 100%. Developing country simulation was for an initial literacy level of 20 percent with negative media credibility and then reversing the credibility level to moderately positive \((0.1, 0.2, 0.3, 0.4\) and 0.5).](image)

This simulation was run for varying levels of source credibility \((0.1, 0.2, 0.3, 0.4\) and 0.5) with the results given in Figure 22. Recovering from initial negative credibility is possible, however the reversal in literacy is not immediate and much of the gain occurs over long durations. Expectations for immediate changes in financial literacy levels after the implementation of a more credible education program are unrealistic.
Figure 22: Developing country simulation was for an initial literacy level of 20 percent with negative media credibility and then reversing the credibility level to positive credibility levels of 0.1, 0.2, 0.3, 0.4 and 0.5 (%).

5. Discussion
A critical concern with many studies of financial literacy is the problem of selection. Individuals who are better equipped to acquire information about financial products may be different than those who do not. If people with high levels of financial literacy are different than those with low levels of financial literacy, then differences in observed outcomes such as retirement savings levels may be due to these unobserved differences rather than financial literacy.

The use of an agent-based model to understand behaviours avoids this problem as it makes no assumption around the selection issue. Changes in literacy levels are modelled using the characteristics of social network influences and information source credibility only, while individuals in the simulation are endowed with random levels of literacy and media susceptibility. The changeable attribute of an agent is its level of financial literacy. Financial literacy in this context refers to the behaviour of individuals employing the use of financial products, no matter how simple (savings account or insurance policy) or complex (derivatives). The attributes given to an agent at creation remain constant throughout each simulation. In reality, financial literacy levels are already clustered geographically rather than being randomly distributed, however this clustering effect somewhat validates the model. If the agents were not fixed in the torus but free to move about the landscape the spill over of
behaviour change between media and no media areas described in Section 4.3 may have been greater.

The link between information source credibility and financial literacy levels was shown to be quite strong, even in weak social networks. This link is even stronger for lower levels of social distance and higher individual strength as seen in many developed countries. The use of financial planners who are assumed to carry high source credibility is strongly correlated with financial literacy levels in developed countries see Huddleston and Danes (1999). The above analysis shows that the same link can be established in developing countries. This has important implications for financial literacy program design and delivery.

While some attempt was made to calibrate the model to results observed in developed and developing countries, validation of the results of social simulations is difficult. Simulations involving large numbers of parameters pose problems for comprehensively exploring the parameter space and running controlled experiments to verify simulation results of complex systems is challenging. Validation is especially challenging when modelled properties of the system are qualitative and the theories that underlie the model are described verbally rather than numerically.

6. Conclusions

The lack of data for financial literacy program success in developing economies requires alternative methods to seek an understanding of how to improve basic financial literacy levels. The approach used in the study employs a simple model of social interaction with exogenous signal influences. The model was simulated for a population of agents varying the variety of parameters as described in the model. We showed that the social network in a population as well as the penetration and credibility levels of the media have a very strong effect on behavioural change in emerging economies. Variations in population access to media and population density also play a large role in the success of financial literacy programs, however the use of a credible source for information to leverage the social learning effect via the strong networks inherent in many emerging economies is likely to yield cost-effective advances in financial literacy levels.
Financial literacy is important for emerging economies since better-educated consumers should make informed financial decisions. The benefits of improved financial literacy to emerging markets are substantial. Individuals may be able save more and better manage risk through insurance and there may even be general equilibrium effects such improvements in risk sharing, a reduction in economic volatility, improved intermediation and the efficiency of financial market development. This may lead to greater competition in the financial services sector and the efficient allocation of capital.

The case for wholesale investment in financial literacy education in developed countries has however not necessarily been established. Education programs need to consider the likely effects on urban and rural populations as well as the time delay in expected financial literacy outcomes.
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